# Using Price Information as an Instrument of Market Discipline in Regulating Bank Risk


Alfred Lehar
University of Vienna
Department of Business Studies

Duane Seppi
Carnegie Mellon University
Tepper School of Business

Günter Strobl*
University of North Carolina
Kenan-Flagler Business School


June 2005

PRELIMINARY AND INCOMPLETE


*Please address correspondence to Günter Strobl, Kenan-Flagler Business School, University of North Carolina at Chapel Hill, McColl Building, C.B. 3490, Chapel Hill, NC 27599-3490. Email: strobl@unc.edu

# Using Price Information as an Instrument of Market Discipline in Regulating Bank Risk

**Abstract**

An important trend in bank regulation is greater reliance on market discipline. In particular, information impounded in securities prices is increasingly used to complement supervisory activities of regulators with limited resources. The goal of this paper is to analyze the theoretical foundations of market-based bank regulation. We find that price information only improves the efficiency of the regulator's monitoring function if the banks' risk-shifting incentives are not too large. Further, if the regulator cannot commit to an ex ante suboptimal auditing policy, market-based bank regulation can lead to more risk taking in equilibrium, increasing the expected payments by the deposit insurance agency. Finally, we show that the regulatory use of market information can decrease the investors' incentives to acquire costly information, thereby reducing the informativeness of stock prices.

# 1 Introduction

Preventing bank failures requires prudent and sophisticated bank supervision. A better assessment of a bank's financial soundness enables the regulator to intervene in a timely fashion and may help avoid a collapse of the financial institution. Banks, however, have become increasingly complicated for regulators to evaluate. Large, multinational banks operate in many markets, under many jurisdictions, and often under the supervision of many national regulators. Complex derivatives and other structured securities are a potential source of substantial risks, but fit only poorly in traditional accounting-based rating schemes of bank regulators.

Bank regulators have responded to these difficulties by greater reliance on market discipline. While the term market discipline is typically loosely defined,[1] the common theme is that the market, with many sophisticated informed investors and analysts, can complement the oversight role of bank regulators with limited resources. The more prominent role of market discipline in banking supervision has been recognized by the Basel Committee on Banking Supervision (2004), which established market discipline as one of the tree pillars of the new Basel Accord (next to capital requirements and auditing).

Using market information for bank supervision and risk assessment has become popular during the last couple of years. Feldman and Schmidt (2003) find that 40% of U.S. supervisory reports contain at least some reference to market data (mostly equity prices and market-based ratios). Moreover, many empirical studies demonstrate that market prices contain valuable information for bank regulators.[2]

[1]Following Bliss and Flannery (2004), we can distinguish between two aspects of market discipline: market monitoring and market influence. Market monitoring reflects the idea that investors collect information on the bank, which is subsequently reflected in securities prices. This information can then be used by bank supervisors or other market participants to discipline a bank for bad behavior. We can observe market influence, when changes in securities prices actually induce changes in the banks behavior. Commonly cited examples of the latter are restricted access to the derivatives market as a consequence of a rating downgrade or risky banks being able to sell their subordinated debt issues at a lower price, thereby increasing their cost of funding. In our paper we focus on market monitoring.

[2]Flannery, Kwan, and Nimalendren (2004) find that bank assets (at least for large banks) are not more opaque than assets of other firms. They do not differ in their trading characteristics and analyst forecasts for banks are actually more precise. Since observed bank defaults are rare, most other studies relate market-based measures of financial distress to other measures of a bank's credit risk based on

The goal of this paper is to analyze the theoretical foundations of regulating banks based on market information. We address three main questions: First, we examine whether price information can improve the efficiency of the regulator's monitoring function, i.e., reduce the regulator's costs from auditing and deposit insurance payments. Second, we analyze how market-based bank regulation affects the bank's risk-taking incentives. Finally, we characterize investors' incentives to gather costly information and thus the endogenous information content of stock prices with market-based auditing policy.

We find that the regulator is better off when the auditing policy is based on market price information only if the bank's risk shifting incentives are sufficiently small. If the incentives to exploit deposit insurance are large, excessive risk taking can only be prevented by auditing the bank even when high stock prices indicate a solvent bank. But auditing the bank when the stock price is high is costly for the regulator because the probability of detecting a bad bank is low in this case. Thus, if the regulator cannot commit to an ex ante suboptimal monitoring policy, market-based bank regulation can potentially lead to more risk taking in equilibrium and may make the regulator worse off. We also find that when risk shifting incentives are sufficiently small, regulatory use of market prices decreases investors' incentives to acquire information and market prices become less informative.

The rest of the paper is structured as follows. Section 2 describes the model. Section 3 analyzes the benchmark case where bank regulation is independent of market information. Section 4 derives the stock market equilibrium. Section 5 derives the regulator's optimal auditing policy. Section 6 analyzes the equilibrium information structure. Section 7 concludes. All proofs are contained in the Appendix.

---

accounting data, rating information, or confidential supervisory ratings. Gropp, Vesala, and Vulpes (2002) analyze the information content of stock and bond-based indicators for European banks. They define banks to have a weakened financial condition, whenever the Fitch rating of financial strength is C or below. They find that an equity-based distance to default measure has high predictive power, whereas subordinated debt spreads have signal value only close to default. Krainer and Lopez (2004) find for a sample of U.S. bank holding companies that equity-based expected default frequencies from KMV can predict changes in supervisory ratings for up to four quarters. There is no clear evidence on whether bond or stock prices are more informative. Most previous studies suggest a mix of both (Bliss (2001), Flannery (2001)).

## 2 The Model

There are three agents in our model: the bank, the regulator, and an informed investor. Figure 1 shows the timing of events.

At time 1, the bank collects \$1 in deposits and invests in either a safe or risky asset. The bank's asset choice is not observable to the regulator. Let $\theta \in \{s, r\}$ denote the asset type and $q$ the probability that the bank chooses the risky asset, i.e., $q = Pr(\theta = r)$. Deposits are fully insured. The return required by depositors therefore equals the riskless rate, which is normalized to zero.

At time 2, shares of the bank are publicly traded in a stock market as described below. At time 3, the return on the bank's asset is realized and depositors are repaid either by the bank or, if the bank's funds are insufficient, by the regulator. The asset's (gross) return is given by

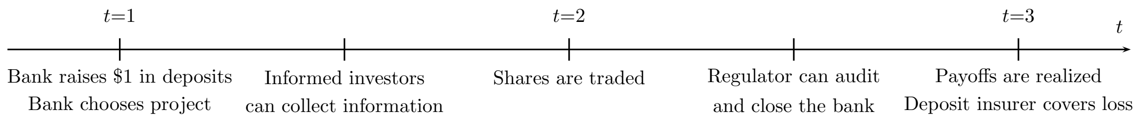
$$R_\theta = 1 + \mu_\theta + \epsilon\, \sigma_\theta, \tag{1}$$

where $\epsilon$ is equally likely to be $+1$ or $-1$. Further, $\mu_s > \mu_r = 0$, $\sigma_s = 0$, and $0 < \sigma_r < 1$. The bank is risk neutral, has no initial capital, and makes its asset choice to maximize its expected equity payoff.

After observing the bank's stock price $P$ at time 2, the regulator decides whether to audit the bank. By incurring a cost $c_A > 0$, the regulator learns two pieces of information. The first is the bank's asset choice $\theta$. The second is an informative signal $s_A \in \{+1, -1\}$ about the expected return $R_\theta$: $Pr(s_A = +1 \mid \epsilon = +1) = Pr(s_A = -1 \mid \epsilon = -1) = (1 + \delta)/2$, where $\delta \in (0, 1)$. Thus, $E[\epsilon \mid s_A] = \delta\, s_A$. We allow for the possibility of mixed strategy equilibria and let $a(P)$ denote the probability that the regulator audits the bank when its stock trades at price $P$. Based on $\theta$, $s_A$, and $P$, the regulator then decides whether to close the bank ($C(\theta, s_A, P) = 1$) or leave it open ($C(\theta, s_A, P) = 0$). If the bank is closed, its assets can be sold for \$$L$. For simplicity, we assume that the return $L$ is the same for all types of assets if they are liquidated prematurely. In the event of liquidation, the regulator pays off the bank's depositors thereby incurring a loss $1 - L$.

At time 3, the regulator repays depositors when the return of the bank's assets are

Figure 1: Timeline.




insufficient. The regulator is risk neutral and chooses $a(P)$ and $C(\theta, s_A, P)$ to minimize its own expected total costs $TC$, which include the payments to depositors and the cost of auditing the bank.

There is a single risk neutral investor who can collect information on the return of the bank's asset before the stock market opens at time 2. By incurring a cost $c_I(\phi) = c_I\,\phi^2$, the investor observes an informative signal $s_I \in \{+1, -1\}$ with probability $\phi$. With probability $1 - \phi$, he does not receive any useful information about $R_\theta$ (denoted by $s_I = \emptyset$). For simplicity, we assume that the precision of the investor's signal is the same as that of the regulator's signal, but the two signals are not necessarily identical. The signal $s_I$ equals $s_A$ with probability $\rho$. With probability $1 - \rho$, it equals a signal that has the same distribution as $s_A$, but is conditionally independent of $s_A$. In other words, the parameter $\rho \in [0, 1]$ measures the correlation between $s_A$ and $s_I$. If $\rho = 1$, the two signals are perfectly correlated, if $\rho = 0$, they are conditionally independent.

The investor chooses the quality of his information production technology $\phi$, taking the bank's asset choice and the regulator's auditing policy as given, even though his choice affects the other agents' optimal strategies. Based on his information, the investor then submits an order for $d_I$ shares of the bank's stock to the market maker.

At time 2, there is a chance of $1-\phi$ that a liquidity trader arrives and trades in the stock market for exogenous reasons. In that event, the liquidity trader is equally likely to be buying or selling one share. Following Dow and Gorton (1997), we assume that the occurrence of a liquidity shock is perfectly negatively correlated with the arrival of an informed investor (i.e., with the event $s_I \neq \emptyset$). Abstracting from the stylized mechanics, the variable $\phi$ is simply a convenient device to represent the endogenous information content of market prices.

The bank's stock is traded in a competitive market-making system and a price is formed in a simplified version of the Kyle (1985) model. Investors and liquidity traders submit their demands to a risk neutral market maker who sets the price $P$ to equal the expected value of a share, conditional on the observed order flow.

## 2.1 Assumptions

The following conditions on the exogenous parameters of the model, $\mu_s$, $\sigma_r$, $\delta$, $\rho$, $L$, $c_A$, and $c_I$, are intended to restrict attention to the more interesting equilibria in which both the bank and the regulator choose mixed strategies.

**Assumption 1**

$$1 - \frac{(2+\delta-\delta^2)\,\sigma_r}{2(2-\delta^2)} < L < 1 - \frac{(2-\delta-\delta^2)\,\sigma_r}{2(2-\delta^2)} \tag{2}$$

Assumption 1 ensures (i) that it is always optimal for the regulator to close a bank with risky assets when the regulator's signal is $s_A = -1$, and (ii) that it is never optimal to close a bank with risky assets when the regulator's signal is $s_A = +1$. This holds for all $\rho \in [0,1]$ and $\phi \in [0, \frac{1}{2}]$.

**Assumption 2**

$$\frac{(1+\delta)\,\sigma_r}{4} < \mu_s < \frac{\sigma_r}{2} \tag{3}$$

This assumption implies that the bank prefers to invest in the risky asset when it is never audited, and to invest in the safe asset when it is always audited.

**Assumption 3**

$$c_A < \bar{c}_A = \frac{(1+\delta)\,\sigma_r}{4} - \frac{1-L}{2} \tag{4}$$

This restriction on $c_A$ ensures that in the case of uninformative stock prices, the expected reduction in deposit insurance payments when auditing a bank with risky assets exceeds the auditing costs.

# 3 Benchmark Case: Optimal Auditing Policy without Stock Price Information

We first analyze the benchmark case, where the regulator's auditing and closure decision is not based on price information. The auditor chooses a constant audit intensity balancing the costs of deposit insurance against the auditing costs.

Without the threat of being liquidated, the bank strictly prefers the risky project. This is not desirable from a welfare perspective.

**Lemma 1** *Under Assumption 2, society always prefers the safe asset over the risky asset, i.e.,* $E[R_r^a] < 1 + \mu_s$*, where*

$$R_r^a = \begin{cases} R_r, & \text{if } s_A = +1 \\ L, & \text{if } s_A = -1 \end{cases} . \tag{5}$$

To derive the equilibrium for the benchmark case, we solve for the optimal strategies of the regulator and the bank. The regulator's objective is to minimize the sum of audit costs and deposit insurance losses.

$$\min_a \; TC = (1-a)\frac{q}{2}\,\sigma_r + a\left[\frac{q}{2}\left(\frac{1+\delta}{2}(1-L) + \frac{1-\delta}{2}(1-L) + \frac{1-\delta}{2}\sigma_r\right) + c_A\right] \tag{6}$$

When there is no audit, the regulator loses \$$\sigma$ if the bank chooses the risky project and the payoff is low. This happens with probability $q/2$. When the supervisor decides to audit, he can detect a bank with a risky project and liquidate it if its payoff is low. This is beneficial to the regulator only if his signal $s_A$ is correct, which happens with probability $(1+\delta)/2$ (first term in the bracket). But since the regulator has only imperfect information on the project outcome, he can make two types of errors. He can incorrectly close a bank with a high expected payoff (second term) or fail to close a bank with a low expected payoff (third term).

The bank chooses its optimal risk level given the regulator's auditing frequency $a$

to maximize the payoff to its equity holders.

$$\max_{q}\,(1-q)\,\mu_s+\frac{q}{2}\left((1-a)+a\,\frac{1+\delta}{2}\right)\sigma_r \tag{7}$$

The bank can either choose the safe project and earn a gross return of \$$\mu_s$ with certainty or invest in the risky project. In the latter case, the equity holders gain if the project turns out to be successful and the regulator does not audit (first term in the bracket) or if the regulator audits and gets a correct signal (second term). Thus, the probability that the regulator inefficiently closes a risky bank with a positive payoff poses a threat to the bank's equity holders which deters them from always investing in the risky project.

We can now solve for the equilibrium in the benchmark case, which is summarized in the following proposition:

**Proposition 1** *If the regulator ignores the information content of the stock price $P$, then there exists a unique equilibrium with the bank's asset choice given by*

$$\hat{q}_{bm}=\frac{4\,c_A}{(1+\delta)\,\sigma_r-2(1-L)},$$

*and the regulator's auditing policy given by*

$$\hat{a}_{bm}=\frac{2(\sigma_r-2\,\mu_s)}{(1-\delta)\,\sigma_r}.$$

*The regulator's expected total costs (payments to depositors and auditing costs) are*

$$TC_{bm}=\frac{\hat{q}_{bm}\,\sigma_r}{2}.$$

# 4 Stock Market Equilibrium

We begin our analysis of the stock market equilibrium by deriving the investor's optimal trading strategy $d_I(s_I)$ and the market maker's pricing rule $P(d)$, taking as given the bank's asset choice $q$, the regulator's auditing policy $a(P)$, and the quality of the investor's information production technology $\phi$.

Since the order submitted by liquidity traders is either $d_L = +1$ or $d_L = -1$, the investor can profitably trade on his information only by buying one share when he receives good news ($s_I = +1$) and selling one share when he receives bad news($s_I = -1$). Indeed, a buy or sell order for any amount other than one share would be identified by the market maker as originating from the investor, thus revealing his information and destroying his opportunity to make a trading profit. Further, buying (selling) shares when $s_I = -1$ ($s_I = +1$) or submitting an order when the signal is uninformative ($s_I = \emptyset$) would generate a loss.[3] Thus, the investor's profit-maximizing trading strategy can be summarized as follows:

$$d_I(s_I) = \begin{cases} +1, & \text{if } s_I = +1 \\ -1, & \text{if } s_I = -1 \\ 0, & \text{if } s_I = \emptyset \end{cases} \tag{8}$$

The market maker sets the price $P$ equal to the expected asset value, conditional on the observed order flow. When the investor follows the trading strategy specified by (8), there are generally two possible prices, one for a buy order and one for a sell order. This is a consequence of our assumption that the occurrence of a liquidity shock is perfectly negatively correlated with the arrival of an informed investor. A buy order could originate from either an informed investor with favorable information or from liquidity traders, and the equilibrium price will reflect the chances of each. Similarly, a sell order could be caused by either liquidity needs or unfavorable information. The following lemma characterizes the equilibrium prices as a function of the observed order flow.

**Lemma 2** *For a given asset choice $q$, auditing policy $a(P)$, and intensity of informed*

[3] This is supported by the following out-of-equilibrium beliefs: If the market maker observes two buy (sell) orders, he updates his probability of state $\epsilon = +1$ ($\epsilon = -1$) to $(1 + \delta)/2$.

*trading $\phi$, the date 2 stock prices are given by*

$$\begin{aligned} P(d=1) &= (1-q)\,\mu_s + q\Big(\tfrac{1}{2}(1+\phi\,\delta) - \tfrac{1}{4}\,a^+(1-\delta)\big(1+\phi(\delta-\rho(1+\delta))\big)\Big)\sigma_r \;\equiv\; P^+, \\ P(d=-1) &= (1-q)\,\mu_s + q\Big(\tfrac{1}{2}(1-\phi\,\delta) - \tfrac{1}{4}\,a^-(1-\delta)\big(1-\phi(\delta-\rho(1+\delta))\big)\Big)\sigma_r \;\equiv\; P^-, \end{aligned}$$

*where $a^+ = a(P^+)$ and $a^- = a(P^-)$.*

Based on these prices and the trading strategy specified by (8), we can now calculate the investor's expected trading profit and his optimal choice of $\phi$, balancing the gains from trade and the cost of information collection:

**Lemma 3** *For a given asset choice $q$ and auditing policy $a(P)$, the investor's expected profit from producing information and trading on it is*

$$\pi_I = \hat{\phi}\,(1-\hat{\phi})\,q\left(\tfrac{1}{2}\,\delta - \tfrac{1}{8}\,(a^+ + a^-)(1-\delta)\big(\delta-\rho(1+\delta)\big)\right)\sigma_r - c_I\,\hat{\phi}^2. \tag{9}$$

*The optimal quality of the information production technology is given by*

$$\hat{\phi} = \frac{1}{2} - \frac{c_I}{q\Big(\delta - \tfrac{1}{4}\,(a^+ + a^-)(1-\delta)\big(\delta-\rho(1+\delta)\big)\Big)\,\sigma_r + 2\,c_I} < \frac{1}{2}. \tag{10}$$

**Corollary 1** *The optimal quality of the investor's information, $\hat{\phi}$, is increasing in the probability $q$ that the bank invests in the risky asset, the variance $\sigma_r$ of the asset return, the signal precision $\delta$, the correlation $\rho$ of the investor's information with the auditor's information, and is decreasing in the information production cost $c_I$. Further, $\hat{\phi}$ is increasing (decreasing) in the auditing frequency, if the correlation between $s_I$ and $s_A$ is sufficiently high (low) in that*

$$\frac{\partial\,\hat{\phi}}{\partial\,a^+} \underset{(<)}{>} 0,\; \frac{\partial\,\hat{\phi}}{\partial\,a^-} \underset{(<)}{>} 0, \qquad if \qquad \rho \underset{(<)}{>} \rho_{crit} = \frac{\delta}{1+\delta}. \tag{11}$$

Most of these comparative statics are intuitive. When the bank invests in the risk-free asset, there are no trading opportunities for the informed trader. Thus, it is not surprising that he invests more in information acquisition when the bank is more likely to invest in the risky project. Information also becomes more valuable when the variation $\sigma_r$ of the project's payoff increases.

The optimal amount of information acquisition of the informed trader also increases in the signal precision $\delta$. Recall that, for algebraic convenience, we assume that $\delta$ is the precision of both the informed trader's signal and of the regulator's signal. The ability to get more precise signals clearly allows the investor to trade more effectively. However, when the regulator's auditing technology improves, he is more likely to close down "bad banks" (i.e., banks that invested in the risky project where the conditional expected payoff is low). This effectively increases the difference between the high and the low stock price. To understand this intuition, consider the case where the regulator always audits and the signal always reveals the true state. Then we know for sure that the bank will be closed in the bad state and will survive in the good state. As the regulator's signal becomes noisier, the probability that the regulator closes a bank with a high (low) expected payoff increases (decreases). This causes the expected value of the bank in the good (bad) state to decrease (increase). Thus, the difference between the high and the low stock price decreases and the informed trader's profit declines.

The investor is also concerned about the correlation of the auditor's signal with his own signal. Since the investor's payoff is affected by both his ability to identify the true state as well as the regulator's action, he has a strong interest in learning the regulator's information. When the correlation of the two signals is high, the regulator's closure policy can be predicted by the informed investor, which makes inside information more valuable to him. When the correlation is low, the regulator is more likely to make a mistake from the informed investor's perspective, which decreases his incentives for information collection.

The same logic applies for the sensitivity of the optimal amount of information collection with respect to the auditing intensity. When the correlation is high, i.e. above the critical threshold $\rho_{crit}$, the informed investor can benefit from higher auditing, because her ability to predict the regulators action is sufficiently high. When the correlation is low, the incentives to collect information decrease as the audit intensity increases, because more auditing increases the risk that the regulator will close the bank when the informed investor receives a favorable signal.

# 5 Optimal Auditing Policy with Stock Price Information

Given the stock market equilibrium in Section 4, we can now derive the optimal strategy of the regulator and the bank. Assumption 1 assures that the regulator, once he has conducted an audit, will always base his closure decision only on his own signal.[4]

Making the audit decision dependent on the observed stock price, the regulator will always find it optimal to audit the bank more frequently (i.e., with a higher probability) when the stock price is low. The reason is that the probability of finding a bank with a low expected project payoff is higher for low stock prices. The regulator will only audit the bank after observing a high stock price if (always) auditing the bank following a low stock price does not suffice to prevent excessive risk taking. The optimal auditing policy with stock price information will therefore depend on the bank's risk-shifting incentives.

**Proposition 2** *Suppose stock prices are informative (i.e., $\phi > 0$) and let*

$$\mu_s^c = \Big(\tfrac{1}{2} - \tfrac{1}{8}(1-\delta)\big(1 - \phi(\delta - \rho(1+\delta))\big)\Big)\sigma_r.$$

*If $\mu_s \geq \mu_s^c$, there exists a unique equilibrium with the bank's asset choice given by*

$$\hat{q}_l = \frac{4\, c_A}{(1+\delta)\big(1+\phi(\delta+\rho(1-\delta))\big)\,\sigma_r - 2\big(1+\phi(\delta^2+\rho(1-\delta^2))\big)(1-L)},$$

*and the regulator's auditing policy given by*

$$\hat{a}_l^+ = 0 \qquad \text{and} \qquad \hat{a}_l^- = \frac{4(\sigma_r - 2\,\mu_s)}{(1-\delta)\big(1-\phi(\delta-\rho(1+\delta))\big)\,\sigma_r}.$$

[4] That is, he always (never) finds it optimal to close the bank when he receives a bad (good) signal, even if the stock price is high (low).

*If $\mu_s < \mu_s^c$, the unique equilibrium is characterized by*

$$\hat{q}_h = \frac{4\,c_A}{(1+\delta)\big(1-\phi(\delta+\rho(1-\delta))\big)\,\sigma_r - 2\big(1-\phi(\delta^2+\rho(1-\delta^2))\big)(1-L)},$$

$$\hat{a}_h^+ = \frac{\big(3+\delta+\phi(\delta(1-\delta)-\rho(1-\delta^2))\big)\sigma_r - 8\,\mu_s}{(1-\delta)\big(1+\phi(\delta-\rho(1+\delta))\big)\,\sigma_r}, \qquad \text{and} \qquad \hat{a}_h^- = 1,$$

*when auditing costs are low ($c_A < c_A^c$), and by*

$$\hat{q}_h = 1, \qquad \hat{a}_h^+ = 0, \qquad \text{and} \qquad \hat{a}_h^- = 1,$$

*when auditing costs are high ($c_A^c < c_A < \bar{c}_A$), where $c_A^c$ is a function of $\delta$, $\rho$, $\phi$, $\sigma_r$, and $L$.*

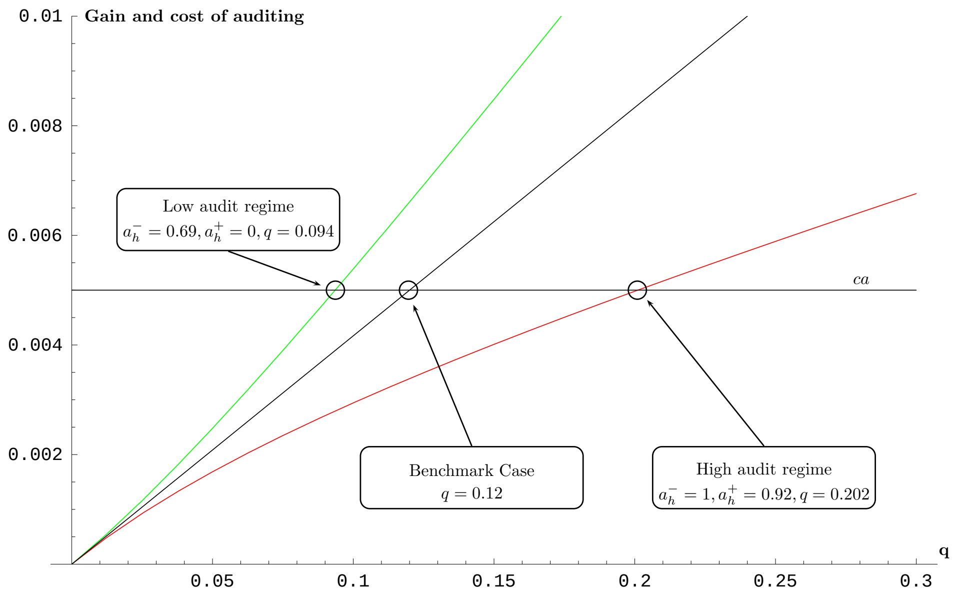
Which of the two auditing regimes occurs depends on the risk-shifting incentives of the bank. When risk taking is not very attractive (i.e., the return on the safe project is high relative to that on the risky project, $\mu_s \geq \mu_s^c$), the regulator audits the bank only when the stock price is low. In other words, if the expected benefit from investing in the risky project does not outweigh the potential loss bank equity holders incur when the regulator closes a solvent bank by mistake, a low audit frequency suffices to prevent excessive risk taking. We refer to this case as the *low-audit regime*. In equilibrium, the bank will be indifferent between choosing the safe and the risky project.

When risk shifting is attractive (i.e., if $\mu_s \leq \mu_s^c$), the regulator can only deter the bank from always investing in the risky project by auditing the bank more frequently, in some cases even when the stock price is high. We call this case the *high-audit regime*.

Auditing at high stock prices is very costly for the regulator, since the probability of finding a "bad bank" is very low in this case. When the auditing costs are too high ($c_A \geq c_A^c$), the regulator will not find it worthwhile to audit the bank when the stock price is high, even if the bank always chooses the risky project. The bank anticipates that the regulator can not commit to such a high auditing frequency and therefore always invests in the risky project.

The goal of market discipline is to create incentives for banks to behave prudently.

Figure 2: Gains and costs from auditing.




We next compare the bank's optimal investment strategy to the benchmark case where the regulator does not condition the audit decision on stock prices.

**Proposition 3** *The bank is less likely to invest in the risky asset in case the regulator's auditing policy takes price information into account, if and only if the return on the safe asset is high in that $\mu_s \geq \mu_s^c$. Thus, the probabilities of investing in the risky asset in the low-audit, high-audit and benchmark equilibria are ordered $\hat{q}_l < \hat{q}_{bm} < \hat{q}_h$.*

Surprisingly, an auditing strategy based on price information does not always induce banks to reduce their risk. When the risky project is very attractive, banks are more likely to choose the risky project under a market-based auditing scheme than in the benchmark case.

Figure 2 illustrates the intuition behind this result by means of a numerical example. When risk shifting is not particularly attractive, we are in the low-audit regime. The regulator has to provide little auditing and can therefore concentrate on auditing when the stock price is low. The regulator can thereby take advantage of information contained in stock prices and perform bank audits more efficiently in those states in which the bank is more likely to realize a low payoff. The three increasing lines in Figure 2 show the benefit to the regulator of conducting an audit for different levels of $q$ in the low-audit regime, the high-audit regime, and the benchmark case, respectively. Of course, auditing is not beneficial when the bank always chooses the safe project ($q = 0$). We find that auditing is very efficient in the low-audit regime as the benefit increases steeply in the probability that the bank picks the risky project. In equilibrium, the bank chooses $q$ such that the regulator is indifferent between auditing and not auditing. In other words, the benefits from auditing must equal the auditing costs $c_A$. In equilibrium, the bank is less likely to choose the risky project than in the benchmark case because the regulator's auditing strategy is more effective.

As the risky project becomes more attractive, the regulator has to increase his level of auditing. Once he has reached the critical level of always auditing the bank after observing a low stock price, a further increase in bank risk leads to a commitment problem for the regulator. Ex ante, he would like to commit to a higher auditing frequency in order to prevent excessive risk taking. Ex post, however, he does not find it optimal to audit the bank when a high stock price indicates that the bank is solvent. Knowing that the regulator cannot commit to an ex post suboptimal auditing policy, the bank will increase its project risk to a level at which the regulator finds it worthwhile to audit the bank even at high stock prices. Thus bank risk is dramatically increasing once we move from the low-audit regime to the high-audit regime.

**Proposition 4** *The regulator's expected total costs (payouts to depositors and auditing costs) in case the regulator's auditing policy takes price information into account are lower than in the benchmark case, if and only if the return on the safe asset is high in that $\mu_s \geq \mu_s^c$. Thus, the regulator's total costs in the high-audit, low-audit and benchmark equilibria are ordered $TC_l < TC_{bm} < TC_h$.*

Proposition 4 shows that the regulator is not always better off when his auditing strategy is based on price information. When risk shifting is not very attractive, we are in the low-audit regime and market information can enhance the effectiveness of bank supervision. In the high-audit regime, however, the bank regulator is worse off.

This has some interesting policy implications. While incorporating market information might save costs during normal times, it might amplify the regulator's cost during a financial crisis. At the brink of a banking crisis, such as the savings and loan crisis, when risk shifting becomes more attractive, the regulator might not be able to commit to audit banks enough and banks' risk as well as the crisis resolution costs will increase.

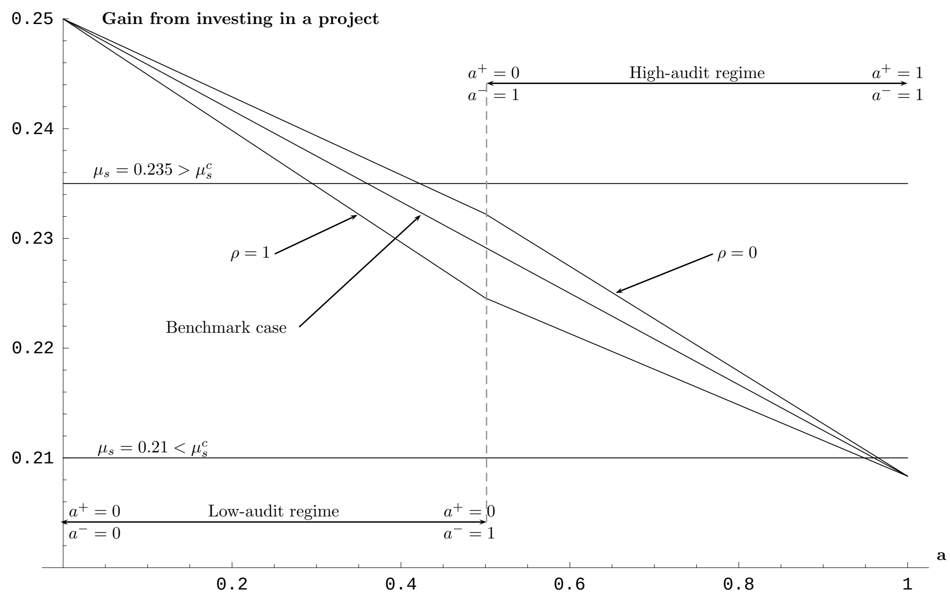
**Proposition 5** *The auditing frequency in case the regulator takes price information into account is lower (higher) than in the benchmark case, if the correlation between the investor's signal $s_I$ and the regulator's signal $s_A$ is high (low), i.e.,*

$$\frac{\hat{a}^+ + \hat{a}^-}{2} \underset{(>)}{<} \hat{a}_{bm}, \qquad \textit{iff} \qquad \rho \underset{(<)}{>} \frac{\delta}{1+\delta}.$$

Proposition 5 compares the equilibrium auditing frequency of the regulator to the benchmark case. Figure 3 illustrates the intuition behind this result. The graph shows the expected bank stock payoff given the safe and risky projects for different levels of auditing. The regulator optimally performs as many audits as necessary in order to make the bank indifferent between the safe project (horizontal lines) and the risky project (downward sloping lines). When risk shifting is not very attractive (i.e., when $\mu_s > \mu_s^c$), the necessary auditing frequency is low and the regulator has to audit the bank only when the stock price is low (low-audit regime). When risk shifting becomes more attractive for the bank (e.g., because the return on the safe project is low, $\mu_s < \mu_s^c$), excessive risk taking by the bank can only be prevented by conducting more frequent audits.

The driving factor for the optimal auditing policy is the correlation between the regulator's signal $s_A$ and the investor's signal $s_I$. With highly correlated signals, fewer audits compared to the benchmark case suffice to deter the bank from always investing in the risky project. The opposite is true for a low correlation. In this case, more audits are necessary to prevent risk shifting than in the benchmark case. The key to understanding this result is very simple. Equity holders do not care whether the regulator closes a bank with a low payoff from the risky project, because their profit would be zero anyway. The equity holders' main concern is that the regulator accidentally

Figure 3: Project payoffs or the bank for different levels of auditing.




closes a bank with a high payoff. For given risk-shifting incentives, we therefore need a certain level of inefficient bank closures to convince equity holders that investing in the safe project is more profitable for them. Thus, the disciplining mechanism for banks is the regulator's threat to close a solvent bank by mistake, thereby destroying the option value of a continued operation to equity holders. When the correlation is high, it is very likely that the regulator will get a bad signal when the stock price is low. Thus, less auditing is required to achieve this target level of bank closures. When the correlation is low, the regulator is less likely to receive an unfavorable signal following a low stock price and therefore has to audit banks more often than in the benchmark case. In the two extreme cases when the regulator never audits or always audits the bank, price information is not important. In these cases, the regulator's behavior only depends on his own information and the bank's gain from investing in the risky project does not depend on the correlation between $s_A$ and $s_I$.

# 6 Equilibrium Information Structure

Most empirical studies explore the possible use of information contained in market prices for bank supervision assuming that the amount of informed trading is exogenous. However, using price information in a market-based auditing process can increase or, potentially, decrease the endogenous informativeness of stock prices.

**Proposition 6** *In the low-audit regime (i.e., when $\mu_s \geq \mu_s^c$), the intensity of informed trading in case the regulator takes price information into account is lower than in the benchmark case, i.e., $\hat{\phi}_l = \hat{\phi}(\hat{q}_l, \hat{a}_l) < \hat{\phi}_{bm}$. In the high-audit regime, however, there exist parameter values such that $\hat{\phi}_h = \hat{\phi}(\hat{q}_h, \hat{a}_h) > \hat{\phi}_{bm}$.*

The informed trader's profits are mainly driven by the bank's willingness to invest in the risky project. Thus, if the bank's risk-taking incentives decrease because of more effective auditing, so does the investor's informational advantage over the market maker and, hence, his expected profit.

Proposition 7 highlights the importance of the correlation between the investor's and the regulator's signal.

**Proposition 7** *The investor's expected profit, $\pi_I$, is strictly increasing in $\rho$, the correlation of her signal, $s_I$, and the regulator's signal, $s_A$. The regulator, on the other hand, benefits from a high correlation $\rho$ if and only if $(\mu_s - \mu_s^c)(L - (1 - \sigma_r/2)) > 0$.*

The investor always benefits from a high correlation, because this makes the regulator's actions more predictable from his perspective. Consider for example an investor who short sells the stock. He does not only gain when the risky project has a bad outcome, but also when the regulator closes the bank. The latter case is more likely to occur when the signal correlation is high.

The regulator does not always prefer a high signal correlation. On the one hand, when the correlation is low, the regulator can learn more about the true state from observing a second signal, which is incorporated in securities prices. On the other hand, when the correlation is high, the regulator is more likely to close a solvent bank by mistake conditional on observing a low stock price. This increases the liquidation threat for the bank and thus makes an investment in the risky project more costly for equity holders.

# 7 Conclusion

Market-based bank auditing seeks to improve the regulatory process by incorporating information contained in market prices. Encouraged by recent empirical studies showing that financial markets can provide valuable information to regulators, bank supervisors hope to increase the efficiency of their monitoring activities and to enhance financial stability. However, including market information in the supervisory process changes investors' incentives to acquire information in the first place and also affects the banks' optimal risk choice. In this paper we analyze the interaction between the banks' risk-taking incentives, the regulator's optimal auditing policy, and the investors' incentives to collect information.

We find that market-based bank regulation makes regulators better off only if banks' risk shifting incentives are not too large. In this case, the regulator is able to extract information from financial markets and can induce banks to invest more prudently by auditing more efficiently. Lower bank risk makes it less attractive for investors to trade on information and security prices become less informative.

In crisis situations, however, when risk shifting is very attractive, regulators are worse off than they would be by ignoring information from financial markets. The main intuition for this result is that regulators hardly find "bad banks" when financial markets give positive signals, which makes auditing very costly in these states of the world. Thus, regulators cannot commit to a strict auditing policy that is suboptimal ex post. Banks anticipate this invest in riskier portfolios, which increase the regulator's cost from deposit insurance payments.

Caution has to be applied when implementing mechanisms of market discipline in bank regulation. While regulators can be better off in times of a stable banking system in which banks have incentives to invest prudently, bank supervisors can be worse off when bank supervision is needed most, namely when the banking sector is fragile and incentives for banks to take excessive risks are high.

# References


Basel Committee on Banking Supervision, 2004, International Convergence of Capital Measurement and Capital Standards: A Revised Framework, .

Bliss, Robert R., 2001, Market discipline and subordinated debt: A review of some salient issues, *Economic Perspectives* 25, 34–45.

Bliss, Robert R., and Mark J. Flannery, 2004, Market Discipline in Governance of U.S. Bank Holding Companies: Monitoring vs. Influencing, *European Economic Review* forthcoming.

Dow, J., and G. Gorton, 1997, Stock Market Efficiency and Economic Efficiency: Is There a Connection?, *Journal of Finance* 52, 1087–1129.

Feldman, Ron J., and Jason E. Schmidt, 2003, Supervisory Use of Market Data in the Federal Reserve System, Working Paper, Federal Reserve Bank of Minneapolis.

Flannery, M., S. Kwan, and M. Nimalendren, 2004, Market Evidence on the Opaqueness of Banking Firms Assets, *Journal of Financial Economics* forthcoming.

Flannery, Mark J., 2001, The Faces Of Market Discipline, *Journal of Financial Services Research* pp. 107–119.

Gropp, Reint, Jukka Vesala, and Giuseppe Vulpes, 2002, Equity and Bond Market Signals as Leading Indicators of Bank Fragility, ECB Working Papers No 150.

Krainer, John, and Jose A. Lopez, 2004, Incorporating Equity Market Information into Supervisory Monitoring Models, *Journal of Money, Credit, and Banking* forthcoming.

Kyle, Albert-S., 1985, Continuous Auctions and Insider Trading, *Econometrica* 53, 1315–1335.

# A List of Variables

| | |
|---|---|
| $\theta$ | bank's asset type, $\theta \in \{s, r\}$ |
| $q$ | probability that the bank chooses the risky asset, i.e., $q = Pr(\theta = r)$ |
| $R_\theta$ | asset return: $R_\theta = 1 + \mu_\theta + \epsilon\, \sigma_\theta$, $\epsilon \in \{-1, +1\}$ |
| $\mu_\theta$ | expected (net) return on the bank's asset |
| $\sigma_\theta$ | standard deviation of the return on the bank's asset |
| $P$ | stock price, $P \in \{P^+, P^-\}$ |
| $c_A$ | auditing costs of the regulator |
| $s_A$ | signal about $\epsilon$ observed by the regulator, $s_A \in \{+1, -1\}$ |
| $s_I$ | signal about $\epsilon$ observed by the investor, $s_I \in \{+1, -1\}$ |
| $\delta$ | informativeness of the regulator's and investor's signal |
| $a(P)$ | audit probability of the regulator as a function of the stock price $P$ |
| $L$ | liquidation value of the bank's assets when the regulator closes the bank prematurly |
| $c_I(\phi)$ | costs of information production for the investor, $c_I(\phi) = c_I\, \phi^2$ |
| $\phi$ | probability that the informed investor observes a signal |
| $\rho$ | correlation of the regulator's and the investor's signal |
| $d_I$ | market order submitted by the investor |
| $d_L$ | market order submitted by the liquidity trader |
| $TC$ | expected total costs of the regulator |

# B Proofs

To be written.